STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
PULLMAN, WASHINGTON

DIVISION OF PLANT PATHOLOGY
AND
AGRICULTURAL ENGINEERING

The Dusting of Wheat for Bunt or Stinking Smut

BY

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*In co-operation with the United States Department of Agriculture.
**In co-operation with Chelan County.

THE DUSTING OF WHEAT FOR BUNT OR STINKING SMUT

By F. D. Heald and L. J. Smith

Introduction

In the control of wheat smut we have passed through two periods: first the **bluestone or copper sulphate period** from the earliest times up to 1897, when formaldehyde was first employed; and second, the **formaldehyde period** from 1897 to the present time. Although the formaldehyde disinfection has very largely replaced the use of bluestone in the eastern United States, the latter has continued to be used quite extensively in the Pacific Northwest since it has been shown to have some effect in reducing the smut in winter wheat due to soil contamination, while formaldehyde has no residual action.1. Although both bluestone and formaldehyde treatments have proved effective in preventing bunt of wheat due to seed-borne spores, both have certain disadvantages and their employment is frequently followed by injurious effects upon the crops.

Disadvantages of and Objections to the Standard Wet Treatments

It has long been recognized that the use of the various bluestone formulae2 causes much reduction in the per cent of germination of treated wheat. Even with close attention to standard recommendations, treated seed may frequently show as low as only 25 to 35 per cent viable, while reductions to 40 to 60 per cent viable are rather common. In addition to the killing effect of the bluestone, there may be a pronounced retardation of growth and a lowered vitality. Young seedlings may be twisted and crippled and the toxic effects persist or are only slowly outgrown. When first introduced formaldehyde was eagerly accepted as a substitute for bluestone since it was claimed to do away with the seed injury. It had the added recommendation of being cheaper and also more convenient, since it is a solution of gas in water and ready to use by diluting to the proper strength. With continued use formaldehyde has also been found to have injurious effects. The reduction in germination per cent of the treated grain may be very slight, especially if the seed is

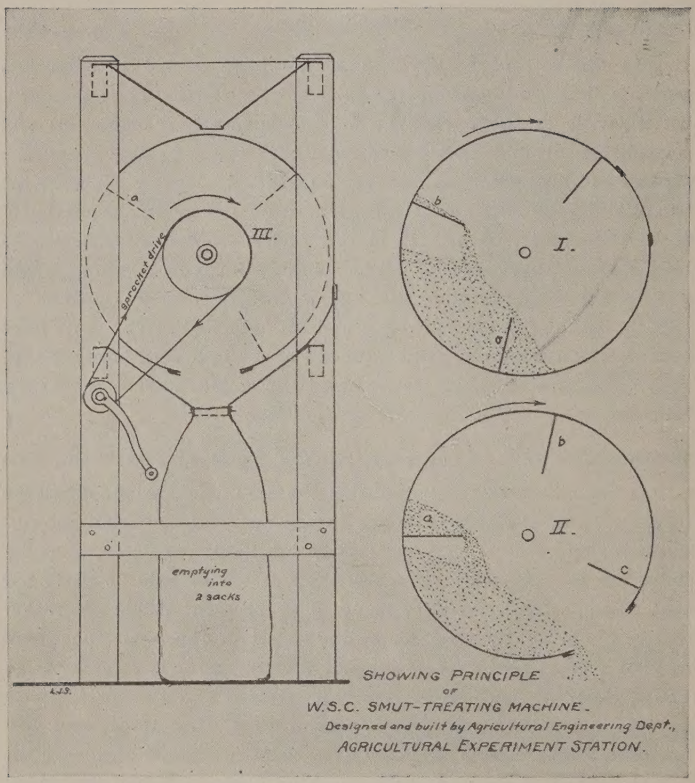

Fig. 1. Diagram showing the principle of the smut-treating machine.. Patents applied for by the Washington Experiment Station, State College.

planted at once in a moist soil, but injury is much more pronounced if the seed is allowed to dry before seeding or if it is seeded in dry soil[2] where it must wait for rains before germination.

It has long been known that an afterbath of bluestone-treated wheat with milk of lime greatly lessens the amount of seed injury, and it has recently been shown that the same method is effective in lessening the injury from formaldehyde. The work of Braun[3] in 1920 showed that pre-soaking would accomplish the same results. While these methods reduce the seed injury and have been recommended for general use, they do not entirely eliminate the depressing effects of the bluestone treatment.

The methods of steeping grain in bluestone or in formaldehyde are inconvenient. The handling of the wet sacks of grain is a disagreeable operation, while the necessity for immersing in two successive baths is an added burden. The necessity for treating grain shortly before seeding, with special precautions concerning drying, makes both of the wet treatments objectionable. The nature of the disinfection has called for the more laborious open-tank method when the seed was heavily smutted. Grain treated by a wet method must also be protected from freezing.

Historical Statement Concerning the Use of Copper Carbonate

Copper carbonate as a fungicide for seed disinfection had been disregarded as its extreme insolubility in water was thought to exclude the possibility of effective action. In the form of a finely powdered dust it was first tested by Darnell-Smith[4] in New South Wales as a fungicide in the control of wheat smut. On the basis of tests conducted in 1915 and 1916 he reported in 1917 that copper carbonate dust gave better results than either formaldehyde or bluestone. A more complete report was issued in 1919, with the claim that machine-treated grain was free from smut while hand-treated grain showed a slight amount of smut. The copper carbonate dust treatment caused no injury to seed or to young plants and also resulted in very substantial increases in yield[5]. The results of Darnell-Smith were questioned by Perkins[6] in 1919 who stated that "we can not, for instance, imagine that a substance wholly insoluble in water can have high fungicidal properties." A discussion of this criticism was published by Darnell-Smith[7] in 1921.

The excellent results obtained in Australia soon attracted the attention of American investigators. Mackie and Briggs[8] first reported experiments in California which corroborated the reports from Australia. They reported in 1921 that spring wheat treated with 2 ounces of copper carbonate dust per bushel was free from

Fig. 2. View of machine and wagon with sack of wheat being emptied into the drum.

smut and suffered no reduction in germination, while the untreated check gave 6.2 per cent of smutted heads.

Lambert and Bailey[9] have just recently reported perfect control of both bunt of wheat and smut of oats by using 2 ounces of copper carbonate dust per bushel. No reduction in germination of oats resulted from using 2 ounces per bushel, while 2 to 10 ounces of the copper carbonate caused no appreciable injury to wheat.

The results from the use of copper carbonate in spring wheat plantings of 1921 were reported by Heald and Smith[10] in June 1922. These results as well as the description of the Washington State College smut-treating machine are repeated in the present bulletin.

Coons[11] has recently reported favorably on the use of copper carbonate for the control of stinking smut in winter wheat in Michigan. Since soil contamination is not a factor in that region, the results can only be compared with our spring seedings.

Comparative Seed Treatments, 1921

Since the favorable results reported by other workers have been substantiated by our own experiments, it has seemed advisable to issue this revised report. The experiments to be reported here covered the seasons of 1921 and 1922.

In our preliminary experiments two varieties of wheat, Bluestem and Jenkins Club, were selected for test. The grain was artificially smutted, using 1 gram of smut to each 100 grams of seed. This is the amount of smut determined by previous experiments[10] as necessary to cause fairly heavy smut but not the maximum amount. The smut was applied by shaking smut and seed together in a large jar; after which the smutted seed was divided into smaller lots, each of which received one of the treatments specified. Each lot was planted in the field in rod rows of carefully spaced seed, and greenhouse germination tests were made to determine the amount of seed injury from the respective treatments. Head and plant counts of the field plots were made at harvest time.

TABLE I.

Comparison of Dust and Wet Seed Treatments
Spring Seeding, 1921

	BLUESTEM			JENKINS CLUB		
Treatment	Per cent germination	Per cent smutted plants	Per cent smutted heads	Per cent germination	Per cent smutted plants	Per cent smutted heads
Check, untreated	84.25	15.06	13.6	89.5	4.6	3 2
Bluestone, wet	67	0	0	65.5	1.2	0.4
Formaldehyde, wet	88.5	0	0	53.5	1.1	0.7
Chorophol, wet	94.5	0	0	96	0	0
Copper carbonate 2 oz. Dust	91.5	0	0	92	0	0
Copper carbonate 4 oz. Dust	98.5	0	0	96.5	0	0
Copper sulphate + calcium carbonate (equal parts) 2 oz. Dust	92.5	0	0	94.5	0	0
Sulphur, 10 lbs. "	89.	0.5	0 2	92.	0	0
Sulphur, 20 lbs. "	94.	0	0	93.5	0	0

The relatively low per cent of smut in both of the checks is explained by the high temperatures and dry conditions immediately following planting, while the smaller amount of smut in the Jenkins Club plots was due to the proximity of these to a row of willow trees which drew very heavily on the soil moisture. It may be noted that perfect control of the smut was obtained by copper carbonate dust and also by the mixture of finely powdered anhydrous copper sulphate (bluestone) and powdered calcium carbonate. The latter mixture will result in the formation of copper carbonate as soon as the

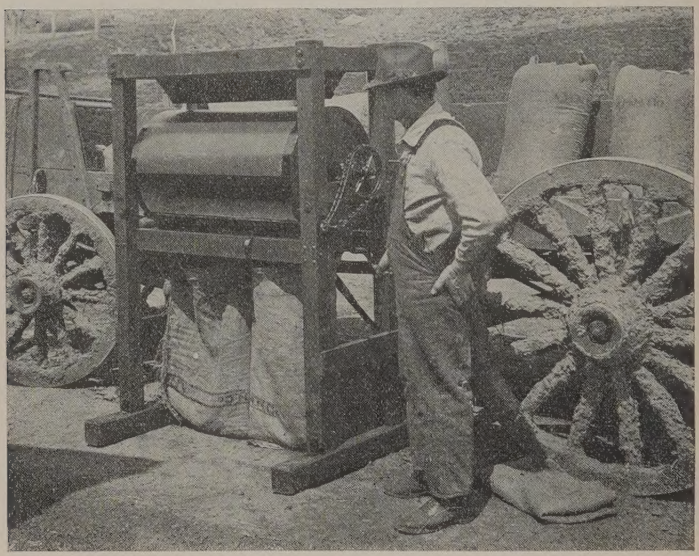

Fig 3. View with drum of machine in position to show the opening and one of the radial mixers or buffers.

treated grain comes in contact with soil moisture and would therefore be expected to give results similar to an initial application of copper carbonate dust. These dust treatments have given an improved germination of the wheat when constrasted with bluestone and formaldehyde disinfection. The value of sulphur dust in smut control is still open to question. Even if it should continue to give the

protection as indicated by these tests, increased yields would be necessary to justify the expense of using the large amount of sulphur.

Comparative Seed Treatments, Spring Wheat, 1922

In the spring plantings of 1922, three varieties were used, Marquis, a resistant "vulgare" type, Bluestem, a susceptible "vulgare" type and Jenkins Club a very susceptible "compactum" type. In each test three different degrees of smutting were employed: light, medium and heavy. The weights of smut per 100 grams of seed and the approximate number of smut spores per grain of wheat were as follows:

Light smut	0.1 grams per 100 gr. of seed,	9,000 spores per grain
Medium smut	0.4 grams per 100 gr. of seed,	36,000 spores per grain
Heavy smut	1.0 grams per 100 gr. of seed,	90,000 spores per grain

The seed was smutted and then treated and planted in the same manner as described in the tests of 1921.

In the first series (Table II), varying quantities of coper carbonate per bushel, from ½ oz. to 3 ozs. were used, in order to determine if possible the minimum quantity necessary to give effective protection. Hydrated lime was used as a diluent for the two lower quantities of carbonate for comparison with the pure copper carbonate. The hydrated lime did not seem to increase the effectiveness of the copper carbonate, but it is significant that one-half ounce per bushel gave nearly as good protection as two ounces. The seed which was heavily smutted was black with smut and was carrying a much larger number of spores than would be found in any ordinary farm practice. The most smut produced by any variety, with medium smutting, even with the reduced quantities of copper carbonate, was 0.9 per cent with an average of 0.21 per cent, while the untreated, medium-smutted lots gave an average of 24.15 per cent of smutted heads. The heavily smutted, treated lots gave an average of 0.97 per cent smutted heads as contrasted with an average of 40.57 per cent smutted heads for the heavily smutted untreated lots. (See Table IV for the untreated checks.)

In a second series of similarly smutted samples (Table III) the seed was treated with varying quantities of finely powdered anhydrous or dehydrated bluestone mixed with equal quantities of finely

powdered calcium carbonate or with hydrated lime. The lots treated with anhydrous bluestone and calcium carbonate gave an average of 1.15 per cent smutted heads, while the corresponding lots treated with anhydrous bluestone and hydrated lime gave an average of 1.65 per cent smut as contrasted with an average of 23.26 per cent in all untreated checks. The average for all copper carbonate tests was 0.41 per cent smutted heads as contrasted with 1.4 per cent smutted heads for all tests with anhydrous bluestone. It seems from these results that anhydrous bluestone is not quite equal to copper carbonate in its protective action and that hydrated lime is not so satisfactory for mixing with the anhydrous bluestone as is calcium carbonate.

In a third series the Corona compound* of copper carbonate was used for comparison with the pure copper carbonate. (Table IV) The average per cent of smutted heads in nine samples given each treatment was as follows:

½ oz. Copper carbonate per bushel,	0.54	per cent smutted heads
1 oz. Copper carbonate per bushel,	0.087	per cent smutted heads
2 ozs. '' carbonate per bushel,	0.290	per cent smutted heads
3 ozs. '' carbonate per bushel,	0.000	per cent smutted heads
2 ozs. Corona compound per bushel,	0.077	per cent smutted heads
4 ozs. Corona compound per bushel,	0.000	per cent smutted heads
No treatment, No. 1.	17.88	per cent smutted heads
No treatment, No. 2.	28.72	per cent smutted heads

The Corona compound contained 17-18 per cent metallic copper as compared with about 50 per cent in the pure copper carbonate. Two ounces of the Corona compound would therefore contain more metallic copper than one-half ounce of the pure carbonate. On the basis of this single test the Corona compound appears, however, to have a better protective action than pure copper carbonate carrying an equal amount of metallic copper.

Seed-o-San, an organic mercury compound furnished by the Standard Tester Co., Chicago, did not give as good protection as a dust fungicide as the copper dusts, although it was very effective for light and medium smutted samples. (Table IV)

*Furnished by the Corona Chemical Division of the Pittsburg Plate Glass Company, Milwaukee, Wisconsin.

TABLE II.

Results in control of stinking smut using varying quantities of copper carbonate. Spring seeding, 1922.

Treatment	Variety	Degree of Smutting	Percent of heads Smutted
Copper Carbonate ½ oz. per bushel	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	.0
	Jenkins Club	Light	.88
		Medium	.0
		Heavy	4.09
Copper carbonate ½ oz. plus hydrated lime ½ oz. =1 oz. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.18
		Heavy	1.08
	Jenkins Club	Light	.0
		Medium	.62
		Heavy	5.41
Copper carbonate 1 oz. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.79
		Heavy	.0
	Jenkins Club	Light	.0
		Medium	.0
		Heavy	.0
Copper carbonate 1 oz. plus hydrated lime 1 oz. = 2 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.36
		Medium	.33
		Heavy	5.07
	Jenkins Club	Light	.0
		Medium	1.0
		Heavy	.14
Copper carbonate 2 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	.89
	Jenkins Club	Light	.0
		Medium	.9
		Heavy	.9

(Continued on next page)

TABLE II.—Continued.

Treatment	Variety	Degree of Smutting	Percent of heads smutted
Copper carbonate 3 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	.0
	Jenkins Club	Light	.0
		Medium	.0
		Heavy	.0

See Table IV. for untreated checks.

TABLE III.

Results in control of stinking smut using varying quantities of anhydrous bluestone. Spring seeding 1922.

Treatment	Variety	Degree of Smutting	Percent of heads Smutted
Anhydrous bluestone ½ oz. plus Calcium carbonate ½ oz. = 1 oz. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.31
		Medium	trace
		Heavy	4.92
	Jenkins Club	Light	.0
		Medium	5.4
		Heavy	.49
Anhydrous bluestone 1 oz. plus Calcium carbonate 1 oz. = 2 ozs. per cushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.27
		Heavy	.74
	Jenkins Club	Light	.37
		Medium	.0
		Heavy	1.15
Anhydrous bluestone 2 ozs. plus Calcium carbonate 2 ozs. = 4 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	4.68
	Jenkins Club	Light	1.28
		Medium	.98
		Heavy	.16

(Continued on next page)

TABLE III.—Continued.

Treatment	Variety	Degree of Smutting	Percent of heads smutted
Anhydrous bluestone ½ oz. plus Hydrated Lime ½ oz. = 1 oz. per bushel.	Marquis	Light	1.11
		Medium	.0
		Heavy	.0
	Bluestem	Light	1.6
		Medium	3.05
		Heavy	10.15
	Jenkins Club	Light	.0
		Medium	2.
		Heavy	.525
Anhydrous bluestone 1 oz. plus Hydrated Lime 1 oz. = 2 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	3.75
	Jenkins Club	Light	.0
		Medium	.825
		Heavy	1.79
Anhydrous bluestone 2 ozs. plus Hydrated Lime 2 ozs. = 4 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	1.62
	Jenkins Club	Light	.88
		Medium	2.54
		Heavy	.0

See Table IV. for untreated checks.

TABLE IV.

Results in control of stinking smut with Corona compound of copper carbonate and Seed-O-San. Checks of untreated smutty seed. Spring seeding, 1922.

Treatment	Variety	Degree of Smutting	Percent of heads smutted
Corona compound of copper carbonate, 2 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	0.25
	Jenkins Club	Light	.0
		Medium	.0
		Heavy	0.45
Corona compound of copper carbonate, 4 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	.0
		Heavy	.0
	Jenkins Club	Light	.0
		Medium	.0
		Heavy	.0
Seed-O-San, 2 ozs. per bushel.	Marquis	Light	.0
		Medium	.0
		Heavy	.0
	Bluestem	Light	.0
		Medium	0.55
		Heavy	3.9
	Jenkins Club	Light	.55
		Medium	.0
		Heavy	1.27
Check No. 1, untreated smutty seed.	Marquis	Light	.61
		Medium	.68
		Heavy	.0
	Bluestem	Light	5.99
		Medium	16.65
		Heavy	54.1
	Jenkins Club	Light	4.2
		Medium	14.3
		Heavy	64.4
Check No. 2, untreated smuutty seed.	Marquis	Light	.33
		Medium	.16
		Heavy	1.66
	Bluestem	Light	6.85
		Medium	56.02
		Heavy	62.7
	Jenkins Club	Light	12.4
		Medium	57.8
		Heavy	60.56

Tests with Winter Wheat, 1922.

A series of tests with winter wheat varieties in cooperation with the Division of Farm Crops was started in the fall of 1921 to determine the comparative value of various seed and soil treatments in the prevention of smut. The previous work with bluestone, formaldehyde and copper carbonate had shown nearly perfect control where only seed-borne smut had to be combatted. The following experiments were carried out on typical summer fallow and were intended therefore to show the comparative value of the different treatments in preventing smut originating from the wind-blown spores. Three varieties were used: Hybrid 128, a very susceptible "compactum" type, Turkey Red, a very resistant variety, and Red Russian, a rather susceptible variety. The seed was not smutted artificially, each lot was given the treatment indicated in the tabulation, and seeded in 1/40 acre plots. This series was also designed to give comparative data on the yield. The smut percentage was obtained by counting a single drill row in each plot, the total number of heads varying from 1000 to 4000.

The results are presented in Table V. No reliable conclusions can be drawn from the data on yield, since there was a marked variation in the soil in the different plots. This was especially noticeable in the Red Russian plots. It may be assumed that the smut in the plots treated with formaldehyde 1-40 (8.3 per cent) originated from soil contamination and that the seed used carried but little smut since the average for the untreated seed was 8.64 per cent of smutted heads. Compared with formaldehyde 1-40, which gives no protection from soil-borne smut, all of the treatments except sulphur 200 lbs. per acre, and replowing the summer fallow, show a reduction in the amount of smut as a result of treatment. The differences are not sufficiently pronounced, however, to justify any conclusion from this series as to the superiority of any one treatment. The small amount of smut in the trench seeding is worthy of note, but the low yield is due to the poor stand as compared with other plots as these plots were planted with a garden seeder. The increase of smut in the replowed summer fallow is contrary to our general experience. During the past season a 65-acre field of replowed summer fallow on the farm of H. H. Curtis, near Pullman, showed only 4.5 per cent of smut, as contrasted with, 4 per cent on the normal summer fallow.

A second series, omitting the different cultural practices, was seeded in duplicate rod-row plots in artificially smutted summer fallow. Just previous to seeding, powdered smut was dusted over the field with a Corona duster, giving as uniform a distribution as possible. The soil was therefore carrying much more smut than normal summer fallow. The results are presented in Table VI. Assuming no protective action from the formaldehyde treatments (Average of 25 per cent smutted heads) all of the copper treatments showed a reduction in the amount of smut as a result of the treatments.

During ths past year comparative tests of bluestone and formaldehyde with copper carbonate were carried out on farms in different parts of the state, the larger number of the tests being supervised by Mr. G. L. Zundel, Extension Pathologist, with the assistance of County Agents. The appended table (Table VII) is a summary from these tests and others arranged for by the Experiment Station Pathologist. Although there were individual cases in which the old treatments gave better results than copper carbonate, the latter gave better average results in all cases.

TABLE V.

Comparative effect of seed and soil treatments in preventing stinking smut in winter wheat planted in ordinary summer fallow. Fall seeding, 1922.

TREATMENT	HYBRID 128		TURKEY RED		RED RUSIAN		Avege. % Smutted heads for three Varieties
	Percent heads Smutted	Bushels per Acre	Percent heads Smutted	Bushels per Acre	Percent heads Smutted	Bushels per Acre	
Sulphur 200 lbs. per A.	17.5	44.3	1.9	36.5	4.8	27.1	8.02
Untreated	17.4	44.5	1.5	36.3	9.8	25.2	9.56
Sulphur 20 lbs. per bu.	6.6	43.7	0.5	35.4	6.2	26.5	4.43
Copper sulphate sprinkle 1 lb. to 1 gallon of water	12.5	42.4	trace	34.4	2.7	24.3	5.06
Copper carbonate 2 ozs. per bu.	13.0	43.5	1.4	36.7	3.2	22.8	5.86
Anhydrous copper sulphate 1 oz. plus calcium carbonate 1 oz.	14.8	42.6	0.5	34.9	3.8	21.3	6.36
Copper sulphate 1-5	10.5	37.8	0.6	40.5	3.8	30.9	4.96
Copper sulphate 1-5 plus lime bath	7.1	41.7	0.7	38.9	3.7	37.7	3.83
Formaldehyde 1-40, customary depth	18.6	40.3	0.6	40.4	5.7	39.9	8.3
Formaldehyde 1-40, shallow drilling	10.4	37.4	0.5	31.8	4.6	34.4	5.16
Formaldehyde 1-40, seed broadcasted	16.7	32.8	1.3	36.9	5.1	27.9	7.7
Untreated	14.7	39.2	1.4	48.1	7.1	43.8	7.73
Formaldehyde 1-40, summer fallow replowed	21.0	39.7	1.6	46.1	10.8	46.2	11.13
Formaldehyde 1-40, trench seeding	5.6	25.7	.5	26.9	3.9	33.2	3.33

TABLE VI.

Comparative effect of seed treatments in preventing smut in winter wheat planted in artificially smutted summer fallow. Fall seeding, 1921.

TREATMENT	HYBRID 128		TURKEY RED		RED RUSSIAN		Avge. % Heads Smutted
	Total Heads	% Smutted Heads	Total Heads	% Smutted Heads	Total Heads	% Smutted Heads	
Sulphur 200 lbs. per A.	185	43.2	307	.00	105	20.9	21.3
Sulphur 20 lbs. per bu.	256	50.3	316	0.1	203	28.5	26.2
Formaldehyde 1-40	312	49.6	360	5.2	243	23.8	26.2
Copper carbonate 2 oz. per bu.	453	36.2	278	3.9	280	13.9	18.0
Anhydrous copper sulphate 1 oz. Calcium carbonate 1 oz.	248	25	306	6.2	222	24.3	18.5
Copper sulphate 1-5	164	6	239	4.3	167	27.5	12.6
Copper sulphate 1-5 plus Lime bath	197	21.3	467	2.9	201	22.3	15.5
Formaldehyde 1-40	186	34.4	363	4.4	235	32.3	23.7
Copper sulphate 1-1 Sprinkle	219	15.9	332	1.5	216	15.7	11.03

TABLE VII.

Smut protection from copper carbonate dust as compared with bluestone and formaldehyde treatments. Farm tests, 1922.

TREATMENTS	No. of Tests	Avge. % Smutted Heads	Maximum % Smutted Heads	No. of tests in which each treatment excelled
Bluestone, standard	26	10.28	31.7	5
Copper carbonate dust 2 oz. per bushel	26	8.47	31.2	21
Bluestone plus Lime bath	8	11.	20.2	1
Copper carbonate 2 ozs. per bushel	8	8.4	12.4	7
Formaldehyde 1-40	20	11.4	35.0	1
Copper carbonate 2 ozs. per bushel	20	5.1	18.7	19

The Effect of Copper Carbonate on Germination and Growth

One of the special values of copper carbonate as a seed fungicide is its non-toxic effect upon the treated grain. The germination tests reported in Table I, show that seed treated with either copper carbonate or anhydrous copper sulphate plus calcium carbonate gave a higher per cent of germination than untreated seed.

The question has been raised as to whether wheat may be dusted with copper carbonate some months previous to seeding time without suffering any injury. In order to test this point, four varieties were given the standard treatment (2 ounces per bushel), and germination tests made at intervals in comparison with untreated seed. The treated and untreated seed was planted in flats in the greenhouse using 200 seed in each lot. The appended table (Table VIII) shows the results obtained up to the present time.

An examination of this table will show not only that no injury resulted for the duration of the test, but that the dusted grain showed an improved germination over the untreated samples.

Mr. Hill, of the Waterville Branch Station, has reported the value of copper carbonate in lessening seed injury for late fall-seeded grain. The data in the appended table (Table IX) are taken from his report, and show the per cent of germination under field conditions. The marked superiority of the copper carbonate over formaldehyde and bluestone is clearly evident.

Besides preventing reduction in germination per cent and thus improving the stand, the copper carbonate treatment induces a more rapid germination and a more vigorous growth. This is especially marked in comparing fields from seed treated with bluestone with fields or plots treated with copper carbonate. In numerous cases of fall-seeded grain, the greater vigor of growth of the copper carbonate-treated field has been very pronounced, even during the early spring. While we have no reliable quantitative data on yields, our cooperators generally agree that the copper carbonate has also given increased yields.

Formula and Methods of Application of Copper Carbonate Dust

On the basis of completed trials our present recommendation is the use of at least 2 ozs. of finely powdered copper carbonate per bushel of wheat. The powder should be fine enought for 98 per

Fig. 4. View of machine with two sacks partially filed. A second lot is treated before the sacks are ready to be removed.

cent. to pass through a 200-mesh sieve and should be of the light fluffy type designed especially for dusting. The heavy copper carbonate,designed for the metallic trades should be avoided. The pure copper carbonate should test at least 50 per cent. metallic copper. The effectiveness of the treatment depends on the uniform distribution of finely divided particles over the surface of the grain. One-half ounce per bushel has given nearly as good protection in spring seeding as 2 ozs. per bushel, while 2 ozs. per bushel of the Corona compound carrying only 18 per cent. copper has given nearly as good protection as 2 ozs. of the pure copper carbonate. Four ounces of the Corona compound per bushel gave perfect protection in spring wheat. Under field conditions giving a relatively low per cent of smut, 2 ozs. per bushel has given perfect protection while with conditions much more favorable for smut, 3 ozs. per bushel has produced a smut-free crop. Considering this fact, the use of 3 ozs. per bushel is worthy of trial for fall-seeded grain, where soil as well as seed-borne smut must be combatted. It may be noted that no harm will result from the use of all the copper carbonate that the seed will carry.

A word of caution may be offered against the possibility of too heavy seeding when using the carbonate treatment. The dry grain feeds faster through the drill than moist grain, the grains are not swollen and there is even an increased germination, hence the grower should set the drill to deliver less seed than has been customary with the old methods.

Since there have been some complaints of illness due to inhalation of copper carbonate dust while carrying out treating operations, farmers are urged to take proper protective measures. The following recommendations are offered: Use some form of respirator to prevent inhalation of dust especiallly if treating operations are to be carried out in a closed room. Dr. W. W. Mackie reports that the Willson Dustite Respirators made by the Willson Goggles Co., Reading, Pa., have been used with complete satisfaction in California, making it possible to work while enveloped in a cloud of the copper carbonate dust. If obliged to work without a respirator, treatments should be carried out in the open, and the apparatus should be so arranged that the wind will carry the dust away from the operator.

TABLE VIII.

Showing germination per cent of untreated and dustedseed of several varieties of wheat.

Date of Test	JENKINS CLUB		HYBRID 128		MARQUIS		JONES WINTER FIFE	
	Untreated	Treated with copper carbonate	Untreated	Treated with copper carbonate	Untreated	Treated with copper carbonate	Untreated	Treated with copper carbonate
February 7	85.	88.5	87.5	92.5	89.5	94.5	95.	90.5
March 8	67.5	90.	75.	60.	96.	85.	91.	96.
April 15	81.5	*	80.	*	84.	*	92.	*
May 8	76.	95.	79.5	89.5	77.	96.	84.	96.
June 24	77.	84.5	80.5	81.5	82.5	91.5	87.	92.
July 19	73.	84.5	83.5	91.	85.	91.5	91.5	94.5
August 22	79.5	78.	71.	87.5	82.	90.	78.5	91.
September 19	84.	83.5	84.	85.	84.5	85.	87.	92.
October 7	80.	81.5	82.5	80.	83.5	85.	82.	584.

TABLE IX.

Germination per cent of Fall-Seeded Wheat.

TREATMENT	Per Cent of Germination	
	HYBRID 128	TURKEY
Untreated seed	90	95
Formaldehyde 1-30	36	45
Formaldehyde 1-50	63	70
Bluestone 1-5	40	52
Copper carbonate 2 ozs. dust	90	95

Even if working in the open, the operator will find a respirator of value if treating grain continuously or for any extended period.

The application of the copper carbonate dust may be made in a number of different ways. In our earliest experimental work the treatment was carried out by shaking the seed and the requisite amount of copper carbonate in a closed container. A barrel churn has been used with good results, while in some larger operations a small concrete mixer has been tried. In some of the demonstration trials the dusting has been accomplished by emptying the wheat and the desired amount of copper carbonate on a canvas and shoveling over the mixture until the grain became thoroughly coated, but this last method is not recommended as it is felt that it gives the least effective distribution of the dust and offers more opportunity for persons doing the treating to inhale the irritating and poisonous dust particles. A special dusting machine has been designed which is effective and also convenient, and it is expected that this or similar machines will come into general use.*

Washington State College Smut-Treating Machine*

In designing a machine for the dry or dust treatment of wheat for smut the following points were kept in mind: (1) To handle the grain as little as possible; (2) To mix the grain and copper carbonate in sack lots; (3) To make the machine self-bagging; (4) To sack the grain in quantities that could easily be handled at the drill; (5) To mix the grain with as few turns of the drum as would give effective distribution; (6) To avoid the disagreeable copper carbonate dust; (7) To build a machine that a farmer having mechanical ability might make.

The accompanying illustration (Fig. 1) shows the principle of the mixer. The drum is revolved until the opening is under the filling hopper. A stop bolt through the vertical post holds the drum in filling position. The helper on the wagon then empties a sack of

*A recent letter from Dr. W. W. Mackie, Office of Cereal Investigations, Washington, D. C., who is stationed at the University of California, contains the following information: "We have perfected and patented an automatic dusting machine with a capacity of more than 300 bushels per hour. This machine takes the graded and cleaned wheat as it comes from the grader and cleaner and dusts it automatically in a confined space which does not permit the escape of dust."

grain into the hopper and it flows into the drum. (Fig. 2). The drum is then turned back so the operator standing on the ground can scatter the copper carbonate uniformly over the surface of the grain, after which the sliding door is put in position and the drum rotated for two minutes. This gives 20 to 30 revolutions per minute which is sufficient to coat thoroughly each grain with the powder.

In the drum there are three wooden radial mixers or buffers, of a width equal to half the radius of the drum (Figs. 1, 3). In position I the grain has slid off the board "b" and is being lifted by "a" during which time it flows over "a" like water over a dam. It should be

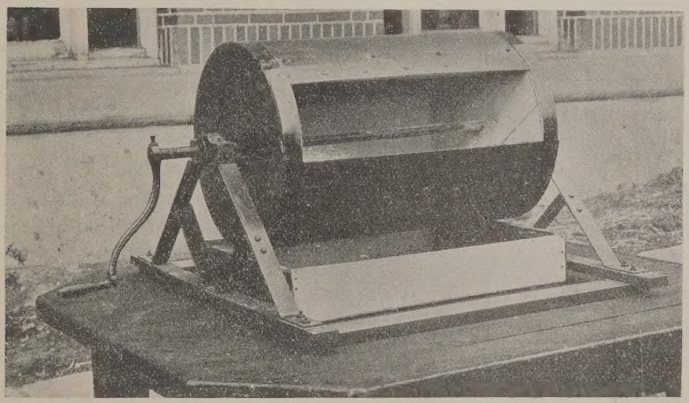

Fig. 5. View of the small dusting machine, which is arranged to empty into a box

noticed that the upper portion of the grain is passing over "a" first. Position II shows the bottom portion of the grain leaving "a" and forming the top of the pile below. Thus the grain is largely reversed in position each time it passes over a mixing-board, making three mixes per revolution of the drum. When the two-minute mixing period is completed, the drum is stopped at its filling position, and the sliding cover is pulled out. The drum is then turned one-half a revolution to position III at which position the treated grain is equally dumped into the two sacks below and is ready to be tied up for use in the field. (Fig. 4).

The ratio of the sprockets is 1 to 4, there being 6 teeth on the drive sprocket and 24 on the drum sprocket. The drum is 21 inches in diameter and 36 inches long. The machine stands five and one-half feet in height. The machine has a capacity of one full sack of wheat, but it is expected that partial sacks (1½ bushels) will be used. In treating a sack of wheat, the crank turns by hand about as hard as a cream separator. One sack can easily be run through every four or five minutes. It would therefore not take long to treat enough seed for a large field.

A blueprint showing all the dimensions of the smut-treating machine will be sent upon application, with a covering fee of twenty-five cents.

The first machine made to test the utility of this principle of mixing is shown in Fig. 5. The drum is 16 inches in diameter and 24 inches long. It was built as an investigational study in Agricultural Engineering by a student, Stephen White, whose ideas assisted very materially in the development of the larger machine. The small mixer will treat one-half bushel at a time. It is about as large as can be conveniently turned with the crank fastened to the axle of the drum, and would do very well for treating seed for small fields.

Advantages of the Copper Carbonate Treatment

The advantages of the dust treatment are so pronounced that this method of control may be expected to replace the older wet treatments with bluestone or formaldehyde. Even though it should give no better protection from smut, we should still continue to recommend it. It is our prophecy that we are now beginning the "copper carbonate period of seed disinfection." The important advantages of this copper carbonate dust may be briefly enumerated as follows:

1. The elimination of the inconvenient and disagreeable soaking methods.

2. The convenience of being able to treat seed days or even months before it is needed for use, thus making possible the utilization of spare time.

3. The elimination of seed injury and retarded growth, with even an improvement in germination over that of untreated seed. This will make possible a reduction in the amount of seed used per acre and should result in a considerable annual saving as soon as the method comes to be generally practiced.

4. The elimination of danger from seeding in the dry, making it possible to seed in the "dust," rather than being obliged to wait for rain.

5. Probable increased yields due to better stands, no retarding influence of the fungicide, and equal or better control of smut.

6. A probable increased protection from reinfection of treated seed by smuty sacks, broken smut balls or from the wind-borne spores that are generally present in our summer fallow fields.

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